U.S. PATENT APPLICATION

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Invention: APPARATUS AND METHOD FOR MAGNETIC RESONANCE IMAGING

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SPECIFICATION

TITLE OF THE INVENTION

APPARATUS AND METHOD FOR MAGNETIC RESONANCE IMAGING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the

5   benefit of priority from the prior Japanese Patent

Application No. 2002-295190, filed October 8, 2002, the

entire contents of which are incorporated herein by

reference.

BACKGROUND OF THE INVENTION

10   1. Field of the Invention

The present invention relates to a magnetic

resonance imaging apparatus and method which are

furnished with MR angiography capable of separating

an artery and a vein without using any contrast medium.

15   2. Description of the Related Art

Magnetic resonance imaging is an imaging method

wherein the atomic nucleus spin of a subject located

in a static magnetic field is magnetically excited by

the radio frequency signal of its Larmor frequency, and

20   wherein an image is reconstructed from a magnetic

resonance signal generated with the excitation.

One imaging method which has recently come into the

limelight in the field of the magnetic resonance

imaging, is MR angiography of the type which does not

25   use any contrast medium.

In the MR angiography, flow pulses are used in

order to dephase or rephase the magnetization spin of

a specified blood flow. Thus, the signal intensity of the specified blood flow is lowered or heightened.

The flow pulses are utilized also for separating and imaging an artery and a vein. By way of example, the artery is assumed an object to-be-handled. Pulse sequences are executed in the diastolic phase and systolic phase of the heart by cardiac synchronization. An image in the diastolic phase and an image in the systolic phase are individually generated, and they are differenced. Thus, the artery is extracted. An extractability here is enhanced by scaling up the intensity difference between an artery signal in the diastolic phase and an artery signal in the systolic phase, and scaling down the intensity difference between a vein signal in the diastolic phase and a vein signal in the systolic phase.

For this purpose, it is important to optimize the time integral value of the intensities of the flow pulses in accordance with blood flow velocities. Since, however, the flow pulses are impressed on the same axis as that of a readout gradient magnetic field for frequency encoding, a temporal space which can be spared for the flow pulses in the pulse sequence is limited. Therefore, the flow pulses cannot be impressed with the optimal time integral value in some cases. Alternatively, an echo time must be sometimes prolonged in order to impress the flow pulses with the

optimal time integral value.

BRIEF SUMMARY OF THE INVENTION

An object of the present invention is to realize MR angiography whose blood flow extractability is high.

In one aspect of the present invention, there is provided a magnetic resonance imaging apparatus, comprising an RF coil unit which generates RF pulses toward a subject, and which receives an MR signal from the subject; gradient magnetic field coils which generate a gradient magnetic field for slice selection, a gradient magnetic field for phase encoding and a gradient magnetic field for frequency encoding, respectively; an arithmetic unit which generates image data on the basis of the MR signal; and a sequence controller which controls the second gradient magnetic field coils in order to generate flow pulses for dephasing or rephasing a spin of a blood flow within the subject, in the same direction as that of the phase encoding gradient magnetic field.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a diagram showing the construction of a magnetic resonance imaging apparatus according to an embodiment of the present invention;

FIG. 2 is a chart showing the temporal relation-ship between a prep (preparatory) scan and an imaging scan in this embodiment;

FIG. 3 is a chart showing the imaging scan of a systolic phase in this embodiment;

FIG. 4 is a chart showing the imaging scan of a diastolic phase in this embodiment;

FIG. 5 is a diagram showing difference processing in this embodiment;

FIG. 6 is a chart showing pulse sequences in this embodiment;

FIG. 7 is a chart showing different pulse sequences in this embodiment;

FIG. 8 is a diagram showing the relationship between a phase encoding (PE) direction and a blood flow direction in FIGS. 6 and 7;

FIG. 9 is a chart showing pulse sequences for imaging blood flow components in the two directions of the phase encoding direction and a readout direction in this embodiment;

FIG. 10 is a chart showing second pulse sequences for imaging blood flow components in the two directions of the phase encoding direction and the readout direction in this embodiment;

FIG. 11 is a chart showing third pulse sequences for imaging blood flow components in the two directions of the phase encoding direction and the readout direction in this embodiment;

FIG. 12 is a chart showing fourth pulse sequences for imaging blood flow components in the two directions of the phase encoding direction and the readout direction in this embodiment;

FIG. 13 is a table showing the differences of the signal intensities of an artery and a vein as depend upon the types of flow pulses, in this embodiment;

FIG. 14 is a flow chart showing the general flow of this embodiment;

FIG. 15 is a chart showing the basic pulse sequences of the prep scan (systolic phase) in FIG. 14;

FIG. 16 is a chart showing the basic pulse sequences of the prep scan (diastolic phase) in FIG. 14;

FIG. 17 is a chart showing the expansive pulse

sequences of the prep scan (systolic phase) in FIG. 14;
and

FIG. 18 is a chart showing the expansive pulse
sequences of the prep scan (diastolic phase) in

5   FIG. 14.

DETAILED DESCRIPTION OF THE INVENTION

Now, an embodiment according to the present
invention will be described with reference to the
drawings.

10   FIG. 1 shows the schematic construction of a
magnetic resonance imaging apparatus according to this
embodiment. The magnetic resonance imaging apparatus
includes a patient couch section on which a patient P
being a subject is laid, a static magnetic field

15   generation section which generates a static magnetic
field, a gradient magnetic field generation section
which serves to add positional information to the
static magnetic field, a transmission/reception section
which transmits/receives an RF (radio frequency)

20   signal, a control/calculation section which takes
charge of the control of the whole system and image
reconstruction, an electrocardiographic measurement
section which measures an ECG (electrocardiogram)
signal being a signal representative of the cardiac

25   phase of the patient P, and a breathholding command
section which commands the patient P to suspend
respiration.

The static magnetic field generation section
includes a magnet 1 of, for example, superconducting
scheme, and a static magnetic field power source 2
which feeds current to the magnet 1. It generates the

5 static magnetic field H0 in the longitudinal direction
(the direction of a Z-axis) of a cylindrical opening
(diagnostic space) into which the subject P is loosely
inserted. Incidentally, a shim coil 14 is disposed
in the magnet section. The shim coil 14 is fed with

10 current for homogenizing the static magnetic field,
from a shim coil power source 15 under the control of
a host computer 6 to be stated later. The patient
couch section can retreatably insert a tabletop bearing
the subject P, into the opening of the magnet 1.

15 The gradient magnetic field generation section
includes a gradient magnetic field coil unit 3 which is
built in the magnet 1. The gradient magnetic field
coil unit 3 includes three sets (sorts) of x-, y- and
z-coils 3x - 3z which serve to generate gradient

20 magnetic fields in the directions of an X-axis, a
Y-axis and the Z-axis orthogonal to one another.
The gradient magnetic field section further includes
a gradient magnetic field power source 4 which feeds
currents to the x-, y- and z-coils 3x - 3z. More

25 specifically, the gradient magnetic field power source
4 feeds the pulse currents for causing the x-, y- and
z-coils 3x - 3z to generate the gradient magnetic

fields, under the control of a sequencer 5 to be stated
later.

When the pulse currents which are fed from the
gradient magnetic field power source 4 to the x-, y-

5   and z-coils 3x - 3z are controlled, the directions of
a gradient magnetic field Gs in a slice direction,
a gradient magnetic field Gpe in a phase encoding
direction and a gradient magnetic field Gro in
a frequency encoding direction (readout direction) can

10   be set and altered at will by combining the gradient
magnetic fields in the directions of the three axes X,
Y and Z. The gradient magnetic fields in the slice
direction, phase encoding direction and readout
direction are superposed on the static magnetic

15   field H0.

The transmission/reception section includes an RF
(radio frequency) coil 7 which is disposed near the
patient P in a radiographic space inside the magnet 1,
and a transmitter 8T and a receiver 8R which are

20   connected to the RF coil 7. Under the control of the
sequencer 5 to be stated later, the transmitter 8T
feeds the RF coil 7 with the RF current pulses of
the Larmor frequency for exciting nuclear magnetic
resonance (NMR), while the receiver 8R receives an MR

25   signal (radio frequency signal) received by the RF coil
7. The received signal is subjected to various items
of signal processing, so as to form corresponding

digital data.

Further, the control/calculation section includes the sequencer (also called "sequence controller") 5, the host computer 6, an arithmetic unit 10, a storage unit 11, a display unit 12 and an input unit 13. Among them, the host computer 6 functions to give the sequencer 5 pulse sequence information in accordance with a stored software procedure, and to generalize the operations of the whole apparatus including the sequencer 5.

The sequencer 5 includes a CPU and a memory, and it stores the pulse sequence information sent from the host computer 6, so as to control the series of operations of the gradient magnetic field power source 4, transmitter 8T and receiver 8R in accordance with the information. Here, the "pulse sequence information" signifies all information items which are required for operating the gradient magnetic field power source 4, transmitter 8T and receiver 8R in accordance with a series of pulse sequences, and it contains, for example, information items on the intensities, impression time periods and impression timings of the pulse currents which are impressed on the x-, y- and z-coils 3x - 3z. Besides, the sequencer 5 receives the digital data (MR signal) outputted by the receiver 8R and transfers the data to the arithmetic unit 10.

The pulse sequences may well be of two-dimensional (2D) scan or three-dimensional (3D) scan if the Fourier transform method is applicable. Besides, regarding the forms of pulse trains, it is possible to apply the SE (spin echo) method, the FE (field gradient echo) method, the FSE (fast SE) method, the EPI (echo planar imaging) method, the fast asymmetric SE method (FASE: technique in which the FSE method is combined with the half-Fourier method), etc.

Besides, the arithmetic unit 10 receives the digital data of the MR signal sent through the sequencer 5 from the receiver 8R, so as to execute the arrangement of original data (also called "raw data") into a Fourier space (also called "k-space" or "frequency space") and two-dimensional or three-dimensional Fourier transform processing for reconstructing the original data into an actual space image, and to execute the synthesis processing of image data. Incidentally, the Fourier transform processing may well be allotted to the host computer 6.

The storage unit 11 can save, not only the original data and reconstruction image data, but also image data subjected to various items of processing. The display unit 12 displays an image. Besides, information items containing the sorts of parameters, a scan condition, the sorts and parameters of pulse sequences, and an image processing method as desired by

an operator, can be inputted to the host computer 6
through the input unit 13.

Besides, a speech generator 19 is included as
a breathholding command unit. The speech generator 19
can vocally emit the messages, for example, of the
start and end of breathholding when commanded by the
host computer 6.

Further, the electrocardiographic measurement
section includes an ECG sensor 17 which is stuck on the
surface of the body of the patient P and which detects
an ECG signal as an electric signal, and an ECG unit 18
which subjects the sensor signal to various items of
processing including digitization processing and which
outputs the processed signal to the host computer 6 and
the sequencer 5. The measurement signal produced by
the electrocardiographic measurement section is used
by the host computer 6 and the sequencer 5 when prep
scan and imaging scan are executed by the cardiac
synchronization method.

Next, the operation of this embodiment will be
described. In this embodiment, as shown in FIG. 2,
the prep scan (preparatory scan) is performed before
the imaging scan. The purpose of the prep scan is to
investigate the optimal scan condition of the imaging
scan. The imaging scan will be first explained,
followed by the prep scan.

As shown in FIGS. 3 and 4, the imaging scan is

performed twice in a systolic phase and a diastolic
phase by utilizing cardiac synchronization. Besides,
as shown in FIG. 5, an image Isys generated from
a magnetic resonance signal acquired in the systolic
phase, and an image Idia generated from a magnetic
resonance signal acquired in the diastolic phase are
differenced by the arithmetic unit 10. Owing to the
differencing, an artery, for example, is extracted
for a target blood flow, and a stationary part and
a vein can be reduced. A condition suitable for the
extraction of the target blood flow is determined by
the prep scan.

Here, when the artery is exemplified for the
target blood flow, the "optimal condition" is a
condition under which the difference of artery signals
becomes large between in the systolic phase and the
diastolic phase, whereas the difference of vein signals
becomes small between in the systolic phase and the
diastolic phase. Flow pulses include the "rephase
type" which heightens signal intensities, and the
"dephase type" which lowers the signal intensities.
Any of three choices; to adopt the rephase type, to
adopt the dephase type, and to use no flow pulses,
is selected. Further, when the flow pulses of the
rephase type or the dephase type are adopted, the time
integral value of the intensities of the flow pulses is
determined.

FIGS. 6 and 7 show two typical sorts of pulse sequences of the imaging scan which applies the FASE method. In the pulse sequences shown in FIG. 6, flow-compensation (flow-comp.) pulses indicated by hatching are adopted as the flow pulses of the rephase type. In the pulse sequences shown in FIG. 7, flow-spoiled (flow-spoil) pulses indicated by hatching are adopted as the flow pulses of the dephase type.

As is well known, the FASE method applies half-Fourier reconstruction to the fast SE method wherein a plurality of echoes are acquired by one time of excitation. Echo signals are arranged from near the center (zero encoding) of the k-space toward the outer edge thereof in succession. Radio-frequency magnetic field pulses (excitation pulses) whose flip angle is 90° are impressed together with slice-selecting gradient magnetic field pulses Gs. Thereafter, while radio-frequency magnetic field pulses (phase-inverted pulses) whose flip angle is 180° are being repeatedly impressed, the echo signals are repeatedly acquired in the existence of frequency-encoding (readout) gradient magnetic field pulses Gro. Since three-dimensional imaging is adopted here, the echo signals are endowed with phase encoding by gradient magnetic field pulses Gpe, and with slice encoding by the gradient magnetic field pulses Gs.

Here, as shown in FIG. 8, a phase encoding

direction PE is set to be substantially parallel to the
direction of the target blood flow (here, artery AR).
Thus, the running direction of the artery AR can be
imaged without being omitted, more clearly than in

5   a case where the phase encoding direction PE is set
at a direction orthogonal to the blood flow direction.
It has been generally known that the blood flow
represented by a pulmonary blood vessel or the hepatic
portal vein is somewhat short in the transverse

10   relaxation time (T2). It has been revealed that the
blood flow of shorter T2 widens in the half-value width
of a signal as compared with the CSF (cerebrospinal
fluid) or articular fluid of long T2. It can be said
that, as compared with the CSF or articular fluid of

15   long T2, the blood of short T2 (artery) is apparently
and equivalently stretched in its width in the phase
encoding direction per pixel. It is accordingly
indicated that the whole image of the blood (artery)
becomes less sharp in the phase encoding direction than

20   that of the CSF or articular fluid.

Therefore, when the phase encoding direction PE is
brought into substantial agreement with the blood flow
direction, it can be positively utilized that the
degree of spread (unsharpness) on the pixel, of the

25   signal value of the blood of short T2 in the phase
encoding direction PE is higher than in the case
of long T2, and the blood flow is emphasized.

Accordingly, when the optimal MRA image (that is, the optimal delay time) for the cardiac synchronization is to be selected as stated above, the selection is more facilitated.

Besides, the flow pulses, the flow-comp. pulses in FIG. 6 or the flow-spoil pulses in FIG. 7 need to be set in the direction of the target blood flow. They can be formed by the phase encoding gradient magnetic field Gpe for the reason that the phase encoding direction PE is brought into agreement with the blood flow direction.

Since the flow pulses are formed by the phase encoding gradient magnetic field Gpe, a temporal margin is afforded more than in case of forming the flow pulses by the frequency encoding gradient magnetic field Gro as in the prior art, and echo intervals can be shortened. Moreover, the flow pulses can be impressed with intensities which are necessary and sufficient for the separation between the artery and the vein.

Incidentally, although in the above, the flow pulses have been impressed in the phase encoding direction so as to image the blood flow in this direction, it is also possible that, as shown in each of FIGS. 9 - 12, flow pulses are impressed, not only in the phase encoding direction Gpe, but also the frequency encoding direction Gro, thereby to image also

a blood flow in this direction.

FIG. 9 shows an example in which flow pulses of
the same type as that in the phase encoding direction
Gpe, here, flow pulses (flow-comp.) of the rephase type
are impressed in the frequency encoding direction Gro.
FIG. 10 shows an example in which flow pulses of the
same type as that in the phase encoding direction Gpe,
here, flow pulses (flow-spoiled) of the dephase type
are impressed in the frequency encoding direction Gro.
FIG. 11 shows an example in which flow pulses of
the type different from that in the phase encoding
direction Gpe are impressed in the frequency encoding
direction Gro. More specifically, the flow pulses
(flow-comp.) of the rephase type are impressed in the
phase encoding direction Gpe, whereas the flow pulses
(flow-spoiled) of the dephase type are impressed in the
frequency encoding direction Gro. Alternatively, the
flow pulses (flow-spoiled) of the dephase type are
impressed in the phase encoding direction Gpe, whereas
the flow pulses (flow-comp.) of the rephase type are
impressed in the frequency encoding direction Gro.
In some cases, as shown in FIG. 12, the blood flow
is emphasized when the flow pulses are not impressed.
Which of the patterns in FIGS. 9 - 12 the flow pulses
are impressed in, is selected depending upon, for
example, the part of the body. By way of example,
the pattern in FIG. 10 is suitable for the periphery,

the pattern in FIG. 11 for the renal vein, and the pattern in FIG. 12 for the chest.

The systolic phase image Isys and the diastolic phase image Idia are acquired by the imaging scan as stated above, and they are differenced simply or in weighted fashion, whereby the artery, for example, is extracted for the target blood flow, and an image in which the stationary part and the vein are reduced is obtained.   The condition suitable for the extraction of the target blood flow is determined by the prep scan. As stated before, the "optimal condition" is defined as the condition under which the difference of the signals from the target blood flow becomes as large as possible between in the systolic phase and the diastolic phase, whereas the difference of the signals from the nontarget blood flow becomes as small as possible between them.

FIG. 13 shows the general tendencies of the respective signal intensities of the artery and the vein in the systolic phase and the diastolic phase, as to the case where the flow pulses are impressed in the rephase type (flow-compensation), the case where the flow pulses are impressed in the dephase type (flow-spoiled), and the case (original) where the flow pulses are not impressed. As stated before, the "optimal condition" for the separation between the artery and the vein is the condition under which the

difference of the signals from the target blood flow becomes as large as possible between in the systolic phase and the diastolic phase, whereas the difference of the signals from the nontarget blood flow becomes as small as possible. They are determined depending upon whether the target blood is the artery or the vein, and also upon the blood flow velocities thereof.

In this embodiment, as shown in FIG. 14, the prep scan is actually executed under various conditions before the imaging scan, and the differenced image between the systolic phase image and the diastolic phase image is generated for each set of the conditions. Further, an operator (inspector) visually checks such differenced images, and he/she selects an image of the highest separability between the target blood flow and the nontarget blood flow from among the differenced images. Thereafter, the imaging scan is executed under the same flow pulse conditions as those of the pulse sequences with which the original signals of the selected image are acquired, that is, the conditions that the flow pulses of the rephase type or the dephase type are impressed or that the flow pulses are not used, and that the same intensities as those of the gradient magnetic field pulses as the flow pulses are set.

FIGS. 15 and 16 show a simple prep scan, while FIGS. 17 and 18 show an example of a prep scan for

setting detailed conditions. The simple prep scan
is done for the purpose of selecting any of the
application of the rephase type flow pulses (flow-
comp.), the application of the dephase type flow pulses
5   (flow-spoiled), and the non-application (original) of
the flow pulses. The detailed prep scan is done for
the purpose of selecting intensities suitable for
the flow pulses, in addition to the selection of any
of the application of the rephase type flow pulses
10   (flow-comp.), the application of the dephase type
flow pulses (flow-spoiled), and the non-application
(original) of the flow pulses. The prep scan of either
of the types is selected by the operator beforehand.

With either of the types, the prep scan is
15   executed by the same method as that of the imaging
scan (here, by the FASE method), but in conformity
with two-dimensional imaging. More specifically,
radio-frequency magnetic field pulses (excitation
pulses) whose flip angle is 90° are impressed together
20   with slice-selecting gradient magnetic field pulses Gs.
Thereafter, while radio-frequency magnetic field pulses
(phase-inverted pulses) whose flip angle is 180° are
being repeatedly impressed, echo signals are repeatedly
acquired in the existence of frequency-encoding
25   (readout) gradient magnetic field pulses Gro. Unlike
the imaging scan, however, the prep scan adopts the
two-dimensional imaging in order to shorten a prep scan

time. Accordingly, the echo signals are endowed with
phase encoding by the gradient magnetic field pulses
Gpe, but they are not subjected to slice encoding.
Besides, in the prep scan, the phase encoding direction
5   PE is set to be substantially parallel to the direction
of the target blood flow (the artery AR in FIG. 8) as
in the imaging scan.

With the simple type, as shown in FIG. 15 or 16,
a two-dimensional FASE-method pulse sequence which
10   applies rephase type flow pulses (flow-comp.), a
two-dimensional FASE-method pulse sequence which
applies dephase type flow pulses (flow-spoiled), and
a two-dimensional FASE-method pulse sequence (original)
which does not apply flow pulses are executed in the
15   systolic phase or the diastolic phase by utilizing
cardiac synchronization.

An image which is reconstructed on the basis of
echoes acquired in the systolic phase by the two-
dimensional FASE-method pulse sequence applying the
20   rephase type flow pulses (flow-comp.), and an image
which is reconstructed on the basis of echoes
acquired in the diastolic phase by the two-dimensional
FASE-method pulse sequence applying the rephase type
flow pulses (flow-comp.) are differenced simply or
25   in weighted fashion, and the differenced image is
displayed.

Likewise, an image which is reconstructed on

the basis of echoes acquired in the systolic phase by

the two-dimensional FASE-method pulse sequence applying

the dephase type flow pulses (flow-spoiled), and

an image which is reconstructed on the basis of echoes

5   acquired in the diastolic phase by the two-dimensional

FASE-method pulse sequence applying the dephase type

flow pulses (flow-spoiled) are differenced simply or

in weighted fashion, and the differenced image is

displayed.

10   Besides, likewise, an image which is reconstructed

on the basis of echoes acquired in the systolic phase

by the two-dimensional FASE-method pulse sequence

not applying the flow pulses, and an image which is

reconstructed on the basis of echoes acquired in the

15 diastolic phase by the two-dimensional FASE-method

pulse sequence not applying the flow pulses are

differenced simply or in weighted fashion, and the

differenced image is displayed.

The operator visually checks the three sorts of

20 images, and he/she selects the image in which the

target blood flow, for example, the artery is extracted

most clearly.

The imaging scan condition is set at the same flow

condition as that of the selected image by the host

25 computer 6 and the sequencer 5. More specifically, in

case of selecting the differenced image between the

image which is reconstructed on the basis of the echoes

acquired in the systolic phase by the two-dimensional
FASE-method pulse sequence applying the rephase type
flow pulses (flow-comp.), and the image which is
reconstructed on the basis of the echoes acquired in
the diastolic phase by the two-dimensional FASE-method
pulse sequence applying the rephase type flow pulses
(flow-comp.), the imaging scan condition is set at
a three-dimensional FASE-method pulse sequence which
applies the rephase type flow pulses (flow-comp.).

Besides, in case of selecting the differenced
image between the image which is reconstructed on the
basis of the echoes acquired in the systolic phase by
the two-dimensional FASE-method pulse sequence applying
the dephase type flow pulses (flow-spoiled), and the
image which is reconstructed on the basis of the echoes
acquired in the diastolic phase by the two-dimensional
FASE-method pulse sequence applying the dephase type
flow pulses (flow-spoiled), the imaging scan condition
is set at a three-dimensional FASE-method pulse
sequence which applies the dephase type flow pulses
(flow-spoiled).

Further, likewise, in case of selecting the
differenced image between the image which is
reconstructed on the basis of the echoes acquired in
the systolic phase by the two-dimensional FASE-method
pulse sequence not applying the flow pulses, and the
image which is reconstructed on the basis of the echoes

acquired in the diastolic phase by the two-dimensional
FASE-method pulse sequence not applying the flow
pulses, the imaging scan condition is set at a three-
dimensional FASE-method pulse sequence which does not

5   apply the flow pulses.

On the other hand, when the prep scan of the
detailed setting type has been selected, it proceeds
as shown in FIGS. 17 and 18. An image which is
reconstructed on the basis of echoes acquired in the

10   systolic phase by the two-dimensional FASE-method
pulse sequence applying the rephase type flow pulses
(flow-comp.) whose flow compensation effect is +3,
namely, whose gradient magnetic field intensity is
triple a reference intensity, and an image which is

15   reconstructed on the basis of echoes acquired in the
diastolic phase by the two-dimensional FASE-method
pulse sequence applying the rephase type flow pulses
(flow-comp.) whose flow compensation effect is +3,
namely, whose gradient magnetic field intensity is

20   triple the reference intensity are differenced simply
or in weighted fashion, and the differenced image is
displayed.

An image which is reconstructed on the basis of
echoes acquired in the systolic phase by the two-

25   dimensional FASE-method pulse sequence applying the
rephase type flow pulses (flow-comp.) whose flow
compensation effect is +2, namely, whose gradient

magnetic field intensity is double the reference
intensity, and an image which is reconstructed on the
basis of echoes acquired in the diastolic phase by the
two-dimensional FASE-method pulse sequence applying the
5   rephase type flow pulses (flow-comp.) whose flow
compensation effect is +2, namely, whose gradient
magnetic field intensity is double the reference
intensity are differenced simply or in weighted
fashion, and the differenced image is displayed.

10   An image which is reconstructed on the basis of
echoes acquired in the systolic phase by the two-
dimensional FASE-method pulse sequence applying the
rephase type flow pulses (flow-comp.) whose flow
compensation effect is +1, namely, whose gradient
15   magnetic field intensity is the reference intensity,
and an image which is reconstructed on the basis of
echoes acquired in the diastolic phase by the two-
dimensional FASE-method pulse sequence applying the
rephase type flow pulses (flow-comp.) whose flow
20   compensation effect is +1, namely, whose gradient
magnetic field intensity is the reference intensity are
differenced simply or in weighted fashion, and the
differenced image is displayed.

Besides, an image which is reconstructed on the
25   basis of echoes acquired in the systolic phase by the
two-dimensional FASE-method pulse sequence not applying
the flow pulses, and an image which is reconstructed on

the basis of echoes acquired in the diastolic phase by
the two-dimensional FASE-method pulse sequence not
applying the flow pulses are differenced simply or
in weighted fashion, and the differenced image is
5   displayed.

An image which is reconstructed on the basis
of echoes acquired in the systolic phase by the
two-dimensional FASE-method pulse sequence applying the
dephase type flow pulses (flow-spoiled) whose flow
10 compensation effect is -1 (flow suppression effect is
+1), namely, whose gradient magnetic field intensity
is the reference intensity, and an image which is
reconstructed on the basis of echoes acquired in the
diastolic phase by the two-dimensional FASE-method
15 pulse sequence applying the dephase type flow pulses
(flow-spoiled) whose flow compensation effect is -1
(flow suppression effect is +1), namely, whose gradient
magnetic field intensity is the reference intensity are
differenced simply or in weighted fashion, and the
20 differenced image is displayed.

An image which is reconstructed on the basis of
echoes acquired in the systolic phase by the two-
dimensional FASE-method pulse sequence applying the
dephase type flow pulses (flow-spoiled) whose flow
25 compensation effect is -2 (flow suppression effect is
+2), namely, whose gradient magnetic field intensity is
double the reference intensity, and an image which is

reconstructed on the basis of echoes acquired in the diastolic phase by the two-dimensional FASE-method pulse sequence applying the dephase type flow pulses (flow-spoiled) whose flow compensation effect is -2 (flow suppression effect is +2), namely, whose gradient magnetic field intensity is double the reference intensity are differenced simply or in weighted fashion, and the differenced image is displayed.

An image which is reconstructed on the basis of echoes acquired in the systolic phase by the two-dimensional FASE-method pulse sequence applying the dephase type flow pulses (flow-spoiled) whose flow compensation effect is -3 (flow suppression effect is +3), namely, whose gradient magnetic field intensity is triple the reference intensity, and an image which is reconstructed on the basis of echoes acquired in the diastolic phase by the two-dimensional FASE-method pulse sequence applying the dephase type flow pulses (flow-spoiled) whose flow compensation effect is -3 (flow suppression effect is +3), namely, whose gradient magnetic field intensity is triple the reference intensity are differenced simply or in weighted fashion, and the differenced image is displayed.

The operator visually checks the seven sorts of images, and he/she selects the image in which the target blood flow, for example, the artery is extracted most clearly.

The imaging scan condition is set at the same flow
condition as that of the selected image by the host
computer 6 and the sequencer 5. More specifically,
in case of selecting the differenced image which

5   corresponds to the two-dimensional FASE-method pulse
sequence that applies the rephase type flow pulses
(flow-comp.) having any of the flow compensation
effects, the imaging scan condition is set at a three-
dimensional FASE-method pulse sequence which applies

10   the rephase type flow pulses (flow-comp.) having the
same flow compensation effect, namely, the same
gradient magnetic field intensity.

Besides, in case of selecting the differenced
image which corresponds to the two-dimensional

15   FASE-method pulse sequence that does not apply the
flow pulses, the imaging scan condition is set at
a three-dimensional FASE-method pulse sequence which
does not apply the flow pulses.

Further, in case of selecting the differenced

20   image which corresponds to the two-dimensional
FASE-method pulse sequence that applies the dephase
type flow pulses (flow-spoiled) having any of the flow
suppression effects, the imaging scan condition is set
at a three-dimensional FASE-method pulse sequence which

25   applies the dephase type flow pulses (flow-spoiled)
having the same flow suppression effect, namely, the
same gradient magnetic field intensity.

Incidentally, the numbers of stages of the flow compensation effect and the flow suppression effect which are attained in the prep scan of the detailed type can be set at will by the operator.

5 As thus far described, according to this embodiment, in an imaging scan, phase encoding pulses Gpe are impressed substantially in agreement with the direction of a target blood flow, and flow pulses are impressed in a phase encoding direction, whereby the 10 effect of emphasizing the blood flow can be realized. Moreover, a temporal margin can be afforded to the flow pulse impression so as to shorten echo intervals and to impress the flow pulses at intensities necessary and sufficient for separating an artery and a vein.

15 Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various 20 modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.